

**SEMICONDUCTOR OPTICAL AMPLIFIER MODULE****CLAIM OF PRIORITY**

This application claims priority to an application entitled "SEMICONDUCTOR OPTICAL AMPLIFIER MODULE," filed in the Korean Intellectual Property Office on May 21, 2003 and assigned Serial No. 2003-32239, the contents of which are hereby incorporated by reference.

**BACKGROUND OF THE INVENTION****1. Field of the Invention**

The present invention relates to a semiconductor optical element, and more particularly to a semiconductor optical amplifier module for amplifying an optical signal entering the semiconductor optical element.

**2. Description of the Related Art**

In typical use are a variety of optical amplifiers for optical communication, one example being an optical fiber amplifier doped with any one of a several rare earth ions, such erbium ions and thulium ions. Such optical fiber amplifiers require that the rare earth ions be pumped to them with a pumping light so that the amplifier can amplify its own received optical signal.

The semiconductor optical amplifier includes a plurality of layers deposited on a semiconductor substrate, i.e., an activation layer having a multi-quantum well, a waveguide

layer serving as an I/O (Input/Output) medium, a clad layer surrounding the waveguide layer, an upper electrode layer, and a lower electrode layer.

Too high an amplification factor for the semiconductor optical amplifier may harm other optical elements connected to the semiconductor optical amplifier and/or may  
5 deteriorate the amplifier's optical signal as evidenced by a low SNR (Signal-to-Noise Ratio). Such SNR characteristics indicate a ratio of signal power contained in an optical signal, present in either a general transmission/reception device (e.g., a receiver or an amplifier) or an optical communication system, to noise power. The SNR characteristics serve as an index for indicating the ratio of an optical signal to noise. The optical signal  
10 power is denoted by "S", and the noise power is denoted by "N".

Maintaining a fixed ratio of entry optical signal to amplified optical signal, i.e., a fixed amplification factor, is very critical to the optimal performance of the semiconductor optical amplifier. A semiconductor optical amplifier module includes a light-receiving element for monitoring the power level of an I/O optical signal, and a controller for  
15 comparing a power level of the optical signal detected by the light-receiving element with a prescribed power level and for maintaining a prescribed, constant amplification gain.

Figures 1 and 2 depict a conventional optical amplifier module. The conventional optical amplifier module includes a semiconductor optical amplifier (SOA) 110, an input unit 140 containing a first detector 160, an output unit 150 containing a second detector 170,  
20 input and output optical fibers 120 and 130, and a controller 180.

One end of the SOA 110 faces the input unit 140 while the other end faces the output unit 150. the SOA 110 amplifies an optical signal 101 applied from the input optical

fiber 120 to the input unit 140, and outputs the amplified optical signal 103 to the output unit 150.

The input unit 140 includes a first collimating lens system 141 for collimating the optical signal 101 received from the input optical fiber 120, a first glass window 142, a first convergence lens system 144 for converging an optical signal collimated by the first glass window 142 at one end of the SOA 110, a first isolator 143 disposed between the first glass window 12 and the first convergence lens system 144, and a first detector 160 disposed between the first glass window 142 and the first isolator 143. The input unit 140 serves as a signal combiner for converging onto the SOA 110 the optical signal 101 received from the input optical fiber 120.

The first collimating lens system 141 collimates the optical signal 101 received from the input optical fiber 120 therein. The first glass window 142 transmits an optical signal collimated at the first collimating lens system 141 to the first isolator 143, and is disposed between the first collimating lens system 141 and the first detector 160.

The first isolator 143 transmits the optical signal it receives from the first glass 142 headed toward the first collimating lens system 144, and cuts off an optical signal transmitted back from the first convergence lens system 144 toward the first detector 160.

The first convergence lens system 144 converges the optical signal generated by the first isolator 143 onto one end of the semiconductor optical amplifier 110.

The first detector 160, disposed between the first glass window 142 and the first isolator 143, includes a reflector 161 for partially reflecting the optical signal transferred from the first glass window 142 to the first isolator 143 perpendicular to a traveling path of

the optical signal, and a first monitor photo-diode 162 for detecting a power level of the optical signal 102 reflected from the reflector 161. The first detector 160 is adapted to monitor an amplification gain of the optical signal 103 amplified by the SOA 110, and detects a power level of the optical signal 101 applied to the SOA 110.

5       The output unit 150 is a combiner for collecting the optical signal 103 amplified by the SOA 110 in the output optical fiber 130 with minimum transfer loss. The output unit 150 includes a second convergence lens system 154 for collimating the optical signal 103 received from the SOA 110, a second isolator 153, a second convergence lens system 151 for converging the amplified optical signal 103 onto one end of the output optical fiber 130, 10 a second glass window 152 for transmitting the amplified optical signal 103 to the second convergence lens system 151, and a second detector 170 disposed between the second isolator 153 and the second glass window 152.

      The second detector 170 includes an beam splitter 172 for dividing a power level of the amplified optical signal 103 traveling from the second isolator 153 to the second glass 15 window 152, and a second monitor photo-diode 171 for detecting a power level of the optical signal 104 divided by the beam splitter 172.

      The controller 180 receives the power level of the optical signal 102 from the first detector 160 and the power level of the power signal 104 from the second detector 170, and compares the power level of the optical signal 102 applied to the SOA 110 with the power 20 level of the optical signal 104 amplified by the SOA 110 to recognize an amplification gain of the SOA 110. The controller 180 compares the power levels of the optical signals 102, 104 detected by the first and second detectors 160, 170, and outputs a control signal to the

SOA 110 to maintain a constant, prescribed amplification gain.

The output optical fiber 130 outputs outside the SOA module a reception optical signal converging on one end of the fiber 130 by means of the second convergence lens system 151 of the output unit 150.

5           However, the conventional SOA module adapts a plurality of detectors each having either a high-priced power divider or a mirror to detect a power level of its own reception optical signal and a power level of an amplified optical signal, resulting in an increased number of fabrication steps and increased production costs. Therefore, the conventional SOA module decreases coupling efficiency between the SOA and an input unit along with  
10   coupling efficiency between the output unit and the output optical fiber, resulting in an increased noise factor of the SOA and a reduced saturation output power.

### **SUMMARY OF THE INVENTION**

Therefore, the present invention has been made in view of the above problems, and, in an aspect of the present invention, an SOA (Semiconductor Optical Amplifier) module  
15   monitors an amplification gain of an amplified optical signal without causing deterioration of the coupling efficiency.

In accordance with the present invention, the above and other aspects can be accomplished by the provision of a semiconductor optical amplifier (SOA) module apparatus that includes a semiconductor optical amplifier (SOA) for amplifying an optical  
20   signal applied to its own first stage, outputting the amplified optical signal at its own second stage, and outputting an ASE (Amplified Spontaneous Emission) light at the first

stage. The module further includes an input unit having a first isolator which transmits an input optical signal to the first stage of the SOA, controls the ASE light received from the first stage of the SOA to separate it from a traveling path of the input optical signal at a prescribed angle, and transmits the ASE light separated from the traveling path. A first  
5 monitor photo-diode with its own light-receiving surface oriented perpendicular to a traveling path of the ASE light emitted from the first isolator detects a power level of the ASE light. An output unit outputs the amplified optical signal received from the second stage of the SOA to the outside, and outputs a partially-uncoupled optical signal created therein for reception by a second monitor photo-diode for detecting an uncoupled optical  
10 signal emitted from the output unit.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

The above and other aspects, features and other advantages of the present invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings, in which the same or similar features are  
15 annotated with identical or analogous numerals throughout the several views:

Fig. 1 is a block diagram of detecting a power of an optical signal applied to a conventional SOA module;

Fig. 2 is a block diagram of detecting a power of an optical signal outputted from a conventional SOA module;

20 Fig. 3 is a block diagram of a SOA module in accordance with a first preferred

embodiment of the present invention;

Fig. 4 is a block diagram of a SOA module in accordance with a second preferred embodiment of the present invention;

Fig. 5a is a graph illustrating a relationship between a power level of an optical signal applied to a SOA shown in Fig. 2 and a power level of an amplified spontaneous emission (ASE) light created at the first stage of the SOA; and

Fig. 5b is a graph illustrating a relationship between a power level of an uncoupled optical signal emitted from an output unit of the SOA and a power level of an output signal amplified by the SOA.

## 10           **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

Preferred embodiments of the present invention will be described in detail with reference to the annexed drawings. In the following description, detailed description of known functions and configurations incorporated herein will be omitted for clarity of presentation.

15           Fig. 3 is a block diagram depicting, by way of non-limitative example, an SOA module in accordance with a first preferred embodiment of the present invention. The SOA module includes an input optical fiber 220, an output optical fiber 230, a SOA 210 for amplifying a received optical signal, an input unit 240 for transmitting an optical signal 201 received from the input optical fiber 220 to one end of the SOA 210, a first monitor photo-  
20   diode 260, an output unit 250 for converging an optical signal 203 amplified by the SOA 210 onto one end of the output optical fiber 230, a second monitor photo-diode 270, and a

controller 280 for controlling an amplification gain of the optical signal 203 amplified by the SOA 210.

The input optical fiber 220 transmits an optical signal to be amplified to the SOA module, and the output optical fiber 230 outputs the optical signal 203 amplified by the SOA 210 to the outside of the SOA module.

The SOA 210 amplifies an applied optical signal 201 at its own first stage, and outputs the amplified optical signal 203 at its second stage. A lower clad layer, an activation layer, and an upper clad layer are sequentially deposited on a semiconductor substrate of the SOA 210. A window layer for restricting a current applied to the activation layer may be deposited on both ends of a ridge stripe disposed at the center of the resultant layer on which the lower clad layer, the activation layer, and the upper clad layer are sequentially deposited. A cap layer may be deposited on the uppermost layer of the SOA. If the input light passes through the activation layer of the SOA 210, the output light of the SOA 210 is amplified by an amplification gain of the activation layer.

The SOA 210 has a configuration similar to that of a semiconductor laser device. However, in contrast to the semiconductor laser device, the SOA 210 deposits an antireflective coating layer on both ends of a cleaved region in such a way that a traveling-wave-type SOA is formed. The SOA 210 outputs the ASE light 202 created therein while amplifying an optical signal through one of its ends serving to receive the optical signal to be amplified.

The input unit 240 includes a first isolator 243, a first collimating lens system 241 for collimating an input optical signal 201, a first glass window 242 for transmitting the



collimated optical signal to the first isolator 243, and a first convergence lens system 244 disposed between the first isolator 243 and the SOA 210. The input unit 240 serves as a combiner for coupling the optical signal 201 received from the input optical fiber 220 with one end of the SOA 210.

5       The first collimating lens system 241 faces one end of the input optical fiber 220, and collimates the optical signal 201. The first glass window 242 is disposed between the first collimating lens system 241 and the first isolator 243, and transmits the optical signal collimated at the first collimating lens system 241 to the first isolator 243.

      The first convergence lens system 244, disposed between the first isolator 243 and  
10   the SOA 210, converges the optical signal received from the first isolator 243 onto a first stage of the SOA 210, and outputs the ASE light 202 emitted from the first stage of the SOA 210 to the first isolator 243.

      The first isolator 243 transmits the optical signal received from the first glass  
window 242 to the first convergence lens system 244, controls the ASE light 202 received  
15   from the SOA 210 to separate it from a traveling path of the optical signal collimated at the first collimating lens system 241 at a prescribed angle to the traveling path, and transmits the ASE light 202 separated from the traveling path. An isolator independent of a polarized light may be adapted as such a first isolator 243, and is made of a birefringence material.

      The first monitor photo-diode 260 is arranged at one end of the input unit 240 to  
20   detect a power level of the ASE light 202 received from the first isolator 243, and outputs the detected power level of the ASE light 202 to the controller 280. For this purpose, the first photo diode 260 is arranged to allow its activation layer (not shown) to be

perpendicular to the traveling path of the ASE light 202.

The output unit 250 serves as a combiner for converging the optical signal 203 amplified by the SOA 210 onto one end of the output optical fiber 230. The output unit 250 includes a second collimating lens system 254 for collimating the optical signal 203 amplified by the SOA 210, a second isolator 253 for transmitting the optical signal collimated at the second collimating lens system 254, a second convergence lens system 251 for converging the optical signal 203 amplified by the SOA 210 onto one end of the output optical fiber 230, and a second glass window 252 disposed between the second isolator 253 and the second convergence lens system 251.

The second collimating lens system 254 faces a second stage of the SOA 210, and collimates the optical signal 203 amplified by the SOA 210.

The second isolator 253 transmits the optical signal collimated at the second collimating lens system 254, controls a partially-uncoupled optical signal 204 to separate it from a traveling path of the optical signal collimated at the second collimating lens system 254 at a prescribed angle to the traveling path, and transmits the uncoupled optical signal 204 separated from the traveling path. The uncoupled optical signal 204 is emitted at a prescribed angle while traveling through the second isolator 253, the optical signal having escaped from the traveling path of the collimated optical signal. An isolator independent of a polarized light may be adapted as such a second isolator 253.

The second glass window 252 is disposed between the second isolator 253 and the second convergence lens system 251, and transmits the collimated optical signal received from the second isolator 253 to the second convergence lens system 251. The second

convergence lens system 251 is disposed between the second glass window 252 and one end of the output optical fiber 230, and converges the optical signal received from the second glass window 252 onto one end of the output optical fiber 230.

Specifically, the output unit 250 converges the optical signal 203 amplified by the SOA 210 onto one end of the output optical fiber 230, and outputs a partially-uncoupled optical signal 204, which, due to reflection or dispersion, escapes from a traveling path of the amplified optical signal 203 toward the output optical fiber.

The second monitor photo-diode 270 detects the uncoupled optical signal 204 created from the second isolator 253 of the output unit 250, and outputs a power level of the uncoupled optical signal 204 to the controller 280. An activation layer (not shown) of the second monitor photo-diode 270 is arranged to be perpendicular to a traveling path of the uncoupled optical signal 204. Specifically, due to reflection or dispersion to create the uncoupled optical signal, its path is diverted away from the output optical fiber 230 and toward the second monitor photo-diode 270 which has been disposed to receive the signal.

The controller 280 compares a power level of the ASE light 202 detected by the first monitor photo-diode 260 with a power level of the uncoupled optical signal 204 detected by the second monitor photo-diode 270, and calculates an amplified gain of the optical signal 203 amplified by the SOA 210. The controller 280 compares a real amplification gain of the SOA 210 with a prescribed amplification gain to be maintained at the SOA 210, and outputs a control signal for allowing the SOA 210 to constantly maintain a prescribed stable amplification gain to the SOA 210.

Fig. 5a depicts a graph illustrating, by way of example and based on exemplary

experimental data, a relationship between a power level of an optical signal applied to the SOA 210 shown in Fig. 2 and a power level of an amplified spontaneous emission (ASE) light created from a first stage of the SOA 210. The X-axis ( $P_{in}$ ) denotes the power level of the optical signal 201 applied to the SOA 210, the left Y-axis ( $P_{out}$ ) denotes a power level of the optical signal 203 amplified by the SOA 210, and the right Y-axis ( $MPD_{in}$ ) denotes a power level of the ASE light 202 detected by the first monitor photo-diode 260 disposed at one side of the input unit 240. As seen from the graph, the power level of the ASE light 202 detected by the first monitor photo-diode 260 is inverse-proportional to the power level of the optical signal 201 applied to the SOA 210.

The box indicated by dotted lines in Fig. 4a denotes an effective detection range 400 for detecting a power level of the optical signal 201 applied to the input unit 240 upon receiving a power level of the ASE light 202 detected by the first monitor photo-diode 260. The effective detection range 400 denotes a prescribed zone wherein the power level of the ASE light 202 detected by the first monitor photo-diode 260 is inversely proportional to the power level of the optical signal 201 applied to the input unit 240. The amplified optical signal readings outside the range 400 represent power levels higher than inverse proportionality would suggest. The effective detection range 400 is therefore confined to 0.0 ~ 0.6 mW, as shown.

Fig. 5b depicts a graph illustrating a relationship between a power level of an uncoupled optical signal emitted from the output unit of the SOA 210 shown in Fig. 2 and a power level of an output signal amplified by the SOA 210. The X-axis ( $P_{in}$ ) denotes a power level of the optical signal 201 applied to the SOA 210, the left Y-axis ( $P_{out}$ ) denotes

a power level of the optical signal 203 amplified by the SOA 210, and the right Y-axis (MPDout) denotes a power level of the uncoupled optical signal 204 detected by the second monitor photo-diode 270 disposed at one side of the output unit 250. As can be seen from the graph, the power level of a partially-uncoupled optical signal 204 created from the output unit 250 varies linearly with the power level of the optical signal 203 amplified by the SOA 210.

Fig. 4 is a block diagram showing a possible embodiment for an SOA module in accordance with a second preferred embodiment of the present invention. As in the first embodiment, the output unit 250 creates a partially-uncoupled signal 204 by diverting the optical signal 203 from its traveling path and at a prescribed angle toward the second photo-detector 270. This second embodiment differs from the first embodiment, however, in that it is the second glass window, rather than the second isolator, which partially uncouples the optical signal 204, and in that the separation in the second embodiment is by means of reflection. Accordingly, in the second embodiment, the amplified optical signal 303 is transmitted by the second isolator 353 to the second glass window 352, and it is the second glass window 352 that creates the partially-uncoupled signal 204. As apparent from the above description, the SOA module according to the present invention detects a power level of a reflection or uncoupled optical signal created from either an isolator or a prescribed module such as a glass window, such that it is not affected by the coupling efficiency of I/O optical signals, and at the same time detects an amplification gain of an optical signal amplified by the SOA, resulting in a minimal noise factor and a minimal saturation output power.

Although the preferred embodiments of the present invention have been disclosed for illustrative purposes, those skilled in the art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope and spirit of the invention as disclosed in the accompanying claims.